Toppersnotes
Unleash the topper in you

THE IIT - JEE SECRET

JEE MAINS AND JEE ADVANCED

PHYSICS

VOL - III

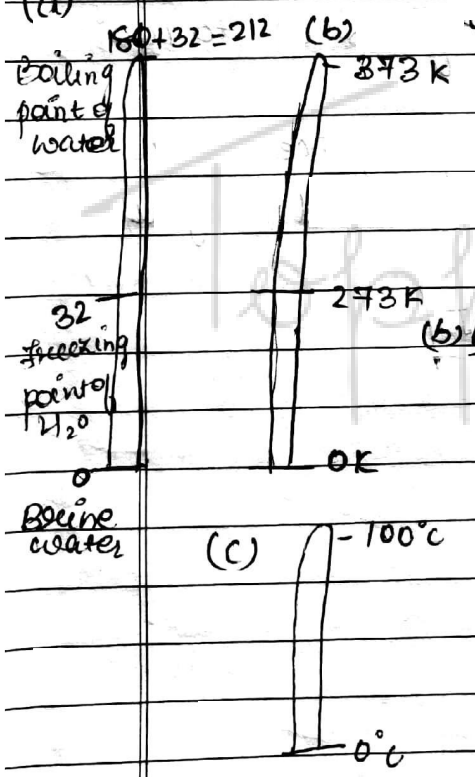
SIERRA INNOVATIONS
Private Limited

Contents

THERMODYNAMICS

Heat :- energy that can flow from one body to another body

Cause of Heat transfer :- temperature diff. and temp. is degree of hot and cold.



(a) Fahrenheit scale

(b) Kelvin scale

(c) Celcius scale

$$\frac{F-32}{212-32} = \frac{C-0}{100-0} = \frac{K-273}{373-273}$$

Value of temp. in °C and °F is same then find its value ?

$$\frac{x-0}{100} = \frac{x-32}{180}$$

$$x = -40$$

Pre SI unit of heat is calorie.

Heat given to increase the temp. of 1gm water by 1°c is 1 calorie. (14.5°C to 15.5°C) This is taken because it is average value of 1/100 of total heat given to increase the temp. from 0° to 100°C)

To displace 1m any object by force 1 N then energy given is called 1 joule

$$\boxed{1 \text{ calorie} = 4.18 \text{ J}}$$

$$Q \propto m \quad \text{—①}$$

$$Q \propto \Delta T \quad \text{—②}$$

From ① and ②

$$Q \propto m\Delta T$$

$$Q = S m \Delta T$$

where,

S = specific heat capacity

$$\frac{Q}{m\Delta T} = S$$

If $m = 1$

$\Delta T = 1$

$$\boxed{Q = S}$$

Amount of heat given to increase the temp. by unit mass to unit then it is called specific heat capacity.

SI unit of $s \Rightarrow$ J/kg K
J/kg °C

$$x \text{ J/kg.K} = y \text{ J/kg.°C}$$
$$x = y$$

Specific heat capacity of any fluid is $2T$, where T is absolute temp.

Q 1 kg subs. is heated from 0°C to 100°C.. Find heat given?

$$Q = s m \Delta T$$
$$dQ = \int ms\,dT$$
$$Q = 1 \times \int 2T\,dt$$
$$= \left[T^2\right]_{273}^{373}$$

During phase change temp. of subs. remains constant.

$$Q \propto m$$
$$Q = mL$$

where,

L → latent heat

Kinetic energy of random motion from centre of mass frame is responsible for temperature

All analysis are purely statistical.

Boiling point

Intense vapourisation point is boiling point.

Kinetic energy of water vapour is much large so that atm. pressure is unable to condense.

When vapour press. of H_2O is slightly greater than atm. pressure.

At 600 Pa boiling point of pure water is 0°C

$-10^\circ C$ ice $\xrightarrow[\Delta T \uparrow]{\text{heat}}$ 0° ice $\xrightarrow[\Delta T = 0]{\text{Heat}}$ 0° water $\xrightarrow[\Delta T \uparrow]{\text{heat}}$ $100^\circ C$ water

$\downarrow$ Heat, $\Delta T = 0$

100° vapour

$S_{ice} = \frac{1}{2}$ cal/gm.°C

$S_{water} = 1$ cal/gm.°C

L_f = latent heat of fusion = solid → liq. = 80 cal/gm

L_v = latent heat of vapour. = liq → vapour = 540 cal/gm

Toppersnotes
Unleash the topper in you

Find heat needed to convert 10 gm ice at -10°c to vapour of 10°C ?

-10° ice ⟶ 0°c ice

$$Q_1 = ms\Delta T$$
$$= \frac{10 \times 1 \times 10}{2}$$
$$= 50 \text{ cal}$$

$$Q_2 = mL$$
$$= 10 \times 80$$
$$= 800 \text{ cal}$$

$$Q_3 = ms\Delta T$$
$$= 10 \times 1 \times 100$$
$$= 1000 \text{ cal}$$

$$Q_4 = mL$$
$$= 10 \times 540$$
$$= 5400$$

Total heat = ~~14900~~ 7700

Law of Calorimetry

Heat gain = Heat loss

(a) 10 gm water 30°C + 20 gm water 80°C

$$= 10 \times 1 \times (T - 30) = 20 \times 1 (80 - T)$$
$$T - 30 = 160 - 2T$$
$$3T = 190$$
$$T = \frac{190}{3}$$

Heat gain = Heat loss

$10 \times 1 \times (T - 30) + 20 \times 1 \times (T - 80) = 0$

$\boxed{m_1 s_1 T_1} + \boxed{m_2 s_2 T_2} + \boxed{m_3 s_3 T_3}$

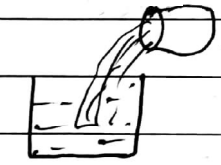
Find final temp.

Let final temp. be T

$m_1 s_1 (T - T_1) + m_2 s_2 (T - T_2) + m_3 s_3 (T - T_3) = 0$

Water Equivalent

Amount of water which absorb same amount of heat to increase the temp. by same amount is called water equivalent of any substance.



milk
m = 40 gm
s = 2 cal/gm °C
T = 80°C

water eqn = 10gm
30°C

Final find final temp.

heat gain = heat loss

$10 \times 1 \times (T - 30) = 40 \times 2 \times (80 - T)$

$T - 30 = 4 \times 160 - 2T \times 4$

$9T = 670$

$T = \frac{670}{9}$

10 gm ice at 0°C + 10 gm water at 30°C
Analyse final temp.

(ice)

Total heat = $Q_1 = mL$

$= 10 \times 80$

$= 800$ cal

Total heat of water = $Q_2 = ms\Delta T$

$= 10 \times 1 \times 30$

$= 300$ cal

$Q = mL$

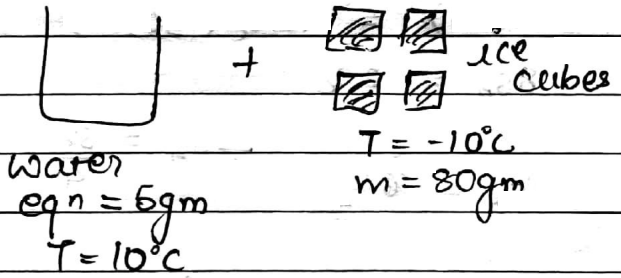
$300 = m \times 80$

$m = \frac{15}{4}$ gm

$q_{ice} = \left(10 - \frac{15}{4}\right)$ gm

water $= \left(10 + \frac{15}{4}\right)$ gm

Combination → at 0°C



Find final temperature

water = $Q = 10 \times 5 \times 1$

$= 50$ cal

ice = $Q = \frac{80 \times 1 \times 10}{2}$

$= 400$ cal

heat given by water equi. $= 5 \times 1 \times (T)$

$= 5T$

Total heat given = $50 + 5T$

$$5T + 50 = 40 \times \frac{1}{2} \times (-T + 10)$$

$$5T + 50 = -40T + 400$$

$$45T = 350$$

$$T = \frac{350}{45} = \frac{70}{9}$$

3 liquids A, B and C are at temp. 10°, 20° and 35° respectively. Same mass of A and B are mixed and resultant temp. is 14°C B and C are mixed with same mass & resultant temp is 28°C What will be the temp. when same mass of A and C are mixed

$$mS_A(T - 10) = mS_B(20 - T)$$

$$4S_A = 6S_B \quad -(1)$$

$$mS_B(28 - 20) = mS_C(30 - 28)$$

$$8S_B = 2S_C$$

$$\frac{4}{6}S_A = \frac{S_C}{4}$$

$$mS_A(T - 10) = mS_C(30 - T)$$

$$\frac{16}{6}S_A(30 - T) = S_A(T - 10)$$

$$T = \frac{270}{11}$$

In a copper calorie meter of water equival 100gm contains ice at -10°C having mass 10gm & 200 gm water at 40°C

is placed in it find final condition of mixture

Total Q for ice to water = 850 $\Rightarrow$ $ms\Delta T$

$= 10 \times \frac{1}{2} \times 10 = 50$ cal

°o ice $\longrightarrow$ water

$= 10 \times 80$

$= 800$ cal

Calorie meter = $ms\Delta T$

$= 100 \times 1 \times 10$

$= 1000$ cal

$= 1000 + 850$

$= 1850$ cal

Q given by water = $ms\Delta T$

$= 200 \times 1 \times 40$

$= 8000$ cal

$Q = ms\Delta T$

$8000 - 1850 = 310 \times 1 \times (T - 0)$

$6150 = 310 \times T$

$T = \frac{615}{31}$

$S_{water} = \frac{4.2\ J}{(\frac{1}{1000})\ kg - °C} = 4200\ J/kg-°c$

$S_{ice} = 2100\ J/kg-°c$

$L_f = 80$ cal/gm

$= 80 \times 4.2 \times 1000$

$= 80 \times 42 \times 100\ J/kg-°c$

Power of heater is 600 watt and 500 gm of water at 0°c is placed into container. water equivalent of container is 1000 gm heat loss in per second in enviroment is 100 watt. Find the time to increase the temp. by 70°C?

$$Q = mS\Delta T$$

$$500T = 1.5 \times 4200 \times 70$$

$$T = \frac{15}{10} \times 70 \times 42$$

$$T = 21 \times 42$$

Find the time to vapourise all water contained

$$500T = 1.5 \times 4200 * 100 + 0.5 \times 540 \times 4200$$

$$500T = 15 \times 420 \times 10 + 5 \times 54 \times 4200$$

$$5T = 15 \times 42 \times 10 + 5 \times 54 \times 42$$

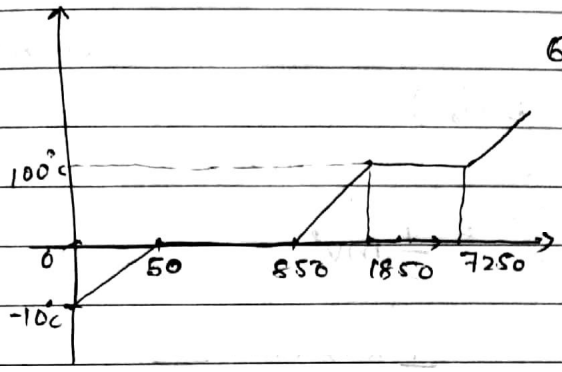
$$T = 30 \times 42 + 54 \times 42$$

$$= 3528$$

Draw graph b/w temp.(y) and heat(x) when 10 gm ice at -10°C is given sufficient heat to form vapour?

$$Q = mS\Delta T$$

$$= \frac{10 \times 1 \times 10}{2} = 50$$



$Q = 100 \times 10$

$= 1000$ cal

Total heat $= 1000 + 850$

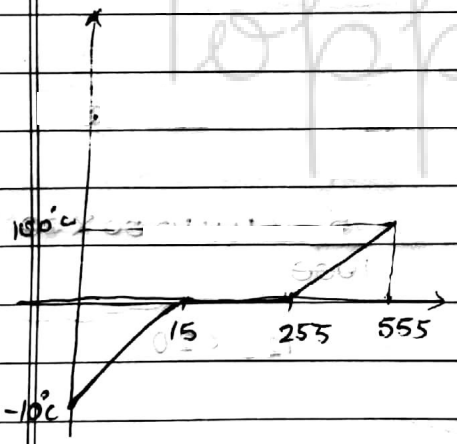
$= 1850$

We can heat at the rate of 10 calorie/second to ice of 30 kg at $-10°C$ till vapourisation. Draw graph b/w temp. (y) and time (x).

$Q = mS\Delta T$

$10t_1 = 30 \times 1/2 \times 10$

$t_1 = 15$



$Q = mL$

$= 30 \times 80 = 2400$

$10t_2 = 2400$

$t_2 = 240 + 15$

$= 255$

$Q = mS\Delta T$

$= 30 \times 1 \times 100$

$= 3000$

$t_3 = 300$ sec

$t_3 = 255 + 300$

Bullet of mass 5 gm specific heat 4 gcal/gm-°c is moving with 10 m/s. It strikes with a large ice cube which is fixed. Find amount of ice melted if initial temp. of

bullet is 30°C and bullet does not melt. (efficency is 50%)

$$\Delta K.E. = \frac{1}{2}mv^2$$

$$= \frac{1}{2} \times 10 \times 10 \times \frac{5}{1000}$$

$$= \frac{5}{20} = 0.25\,J$$

$$1\,cal = 4.2\,J$$

$$= \frac{0.25}{4.2}\,cal$$

$$Q = \frac{1}{8}\,J$$

$$Bullet = ms\Delta T$$

$$= \frac{5}{1000} \times 4200 \times 30$$

$$= \frac{5}{1000} \times 4 \times 4200 \times 30$$

$$= 126 \times 20$$

$$= 2520$$

$$\Rightarrow \frac{1}{8} + 2520 = m \times 80 \times 4200$$

$$\frac{1 + 2520 \times 8}{8 \times 80 \times 4200} = m$$

$$\frac{20161}{640 \times 4200} = m$$

Heat Capacity

It is a product of mass and specific heat.

A calorimeter having mass 100gm and water equivalent is 150gm. Find specific heat capacity of calorimeter?

$$C = ms$$

$$Q = ms\Delta T$$

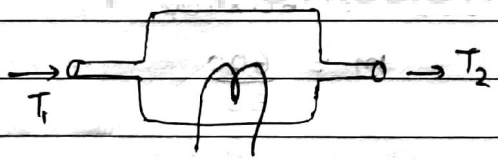
$$= 100 \times s \times \Delta T$$

$$Q = 150 \times 1 \times \Delta T$$

~~$100 \times s \times 150$~~ $\quad 100 \times s = 150$

$$s = 1.5$$

Geyser



$\dot{m} = \frac{dm}{dt}$ = mass / time

$$\frac{d\theta}{dt} = \frac{dm}{dt} \cdot s \cdot (T_2 - T_1)$$

$$\frac{d\theta}{dt} = P = \dot{m} s (T_2 - T_1)$$

In a geyser rate of water flow is 100gm/s inlet temp. = 30°C and outlet temp. = 60°C efficiency of heater is 60%, then find the power of heater in kw.

$$P = 100 \times 1 \times (60 - 30)$$

$$= 3000 \text{ cal/sec}$$

$$P_{water} \times 60\% = 3000$$

$$P \times \frac{60}{100} = 3000$$

$$P = 5000 \text{ cal/sec}$$

$$P = 5000 \times 4.2$$

$$= 21000 \text{ J/sec}$$

$$= 21 \text{ KW}$$

100gm water is at 30°C, to heat we use vapour of 100°C. If final temp. is 90°C then find the amount of steam?

Heat given by steam = heat absorbed by water

$$m \times 540 + m \times 10 \times 1 = 100 \times 1 (90 - 30)$$

$$550m = 60 \times 100$$

$$m = \frac{600}{55}$$